Microplastics as Contaminants of Emerging Concern

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Outline

- What are microplastics?
- Where are microplastics found?
- What are ecological implications?
- What are human health implications?
- What is the impact on New Jersey?

Credit: 5Gyres

Physical Description

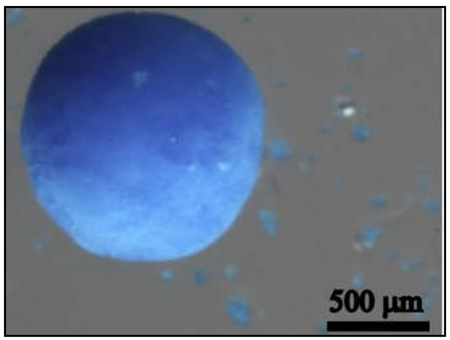
- Microplastics have a diameter <5 mm
- Nanoplastics have a diameter <0.1 μm
- Composed of (partial list): polyethylene, polypropylene, polystyrene, polyester, polyacrylates, and nylon

Size	Description
5 mm	***<u>Upper</u> size limit of microplastics***
2.5 mm	Size of a flea
330 μm	Lower size limit of neuston nets
200 μm	**Microplastic** fragments in a facial scrub
100 μm	Thickness of a sheet of paper
7 μm	Diameter of red blood cells
5 μm	**Microplastic** particles in toothpaste
1 μm	Width of anthrax bacterium
100 nm	***<u>Upper</u> size limit of nanoplastics***
20 nm	Diameter of small viruses
2 nm	Diameter of DNA
1 nm	Diameter of carbon nanotube (single-walled)

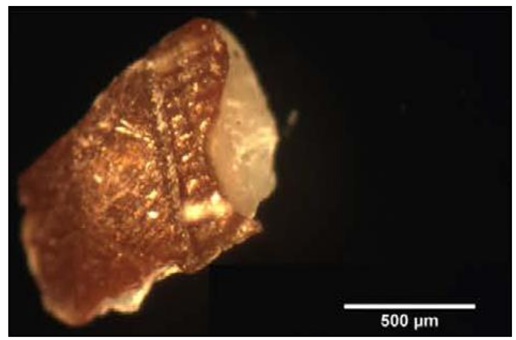
Sources: http://www.nano.gov/nanotech-101/what/nano-size; http://www.nist.gov/pml/wmd/metric/upload/size-and-scale-sesson.pdf

Physical Description (cont'd)

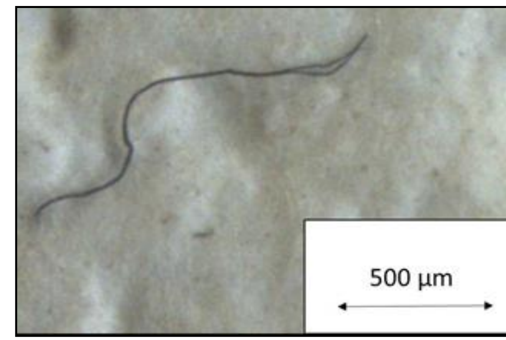
- Microplastics are not just "microbeads"



microbead



fragment



fiber

- Shape(s) of environmental nanoplastics unknown
  - – Limited sampling technology

Sources: microbead, Fedell et al (2009). 58:1225; fragment, Rochman et al (2015). 5:14340; fiber, Gasperi et al (2015). 4:18

Sources into the Environment

- **Primary microplastics**: intentionally manufactured at the microscopic level
  - Microbeads in personal care products
  - Media for air-blasting machinery or boat hulls
  - Pre-production plastics (nurdles)
- **Secondary microplastics**: degradation of larger plastic items
  - Photolytic
  - Mechanical
  - Biological
- **Clothes washing**: shedding of synthetic fibers (e.g., polyester)

Microbeads as a Source of Microplastics

- Used in personal care products (e.g., facial cleansers, soaps, toothpaste) as exfoliants or for aesthetics; typically polyethylene

- Enter wastewater treatment plants and either retained in sewage sludge or introduced into environment via effluent

- Estimated 19 tons of microbeads enter wastewater treatment plants in the state of New York each year[1]

- Estimated 8 billion microbeads enter aquatic environments each day in US[2,3]

1) Report from NY State Attorney General's Office (Nalbone, 2014); 2) Rochman et al. (2015) 49:10759; 3) Rochman et al. (2015) 49:14740

Legislation to Ban Microbeads

- In March 2015, New Jersey passes law to ban “non-biodegradable” microbeads from personal care products *(Effective date January 2018)*

- Bans in other states (as of September 2015): Illinois, Maine, Colorado, and Wisconsin

- In December 2015, Microbead-Free Waters Act of 2015 is a federal ban on the manufacture and use of microbeads; amends the Federal Food, Drug, and Cosmetic Act (*Effective date July 2017*)

- Scope of legislation
  - States: “non-biodegradable” vs “biodegradable”
  - Federal: “rinse-off cosmetics” including toothpaste (excludes lotions, deodorants, household cleaners)

- Bans on microbeads aim to mitigate the microplastics issue
  - Other sources of microplastics and microbeads from other geographic locations still present in the environment

Environmental Measurements

- Environmental contamination with microplastics first detected in early 1970s in NW Atlantic Ocean

- Presently detected throughout the world in:
  - Oceans
  - Artic Sea ice
  - Fresh water (rivers, the Great Lakes)
  - Sediment
  - Organisms

Neuston net

- Abundance in aquatic environments varies by location: 3–100,000 particles per m^3

- Population density is one factor that may influence abundance

- Little research regarding microplastics on land and in the air

Source of picture: Reisser (2013). 8:e80466

Ecological Observations

- Microplastics: found in various trophic levels, based on laboratory and field observations
  - Plankton
  - Invertebrates (worms, shellfish)
  - Vertebrates (fish, mammals)

20 μm polystyrene microplastics in a copepod

- Nanoplastics: evidence for uptake by algae, zooplankton, mussels, based on laboratory observations

- Microplastic ingestion by species consumed by humans

Source of picture: Cole et al (2014). 4:4528

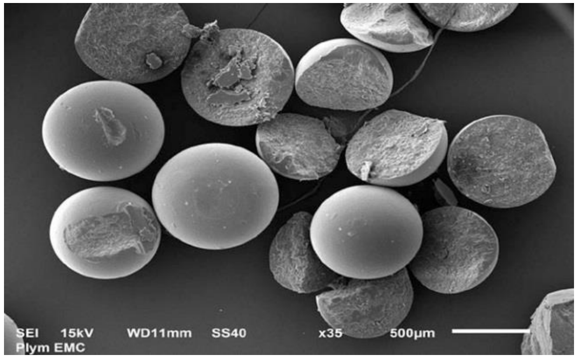
Ecological Effects

- Primarily based on laboratory observations

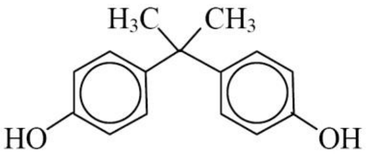
	Organism	Observation
Microplastic	Lugworm	• Decreased feeding, energy, and lipid reserves • Increased reactive oxygen species
	Mussels	• Immune response
	Fish (medaka)	• Hepatic stress • Altered gene expression
Nanoplastic	Algae	• Decreased photosynthesis • Increased reactive oxygen species
	Sea urchin embryo	• Altered gene expression
	Fish (carp)	• Altered lipid metabolism • Altered behavior
Contents herein are a representative list of observations.		

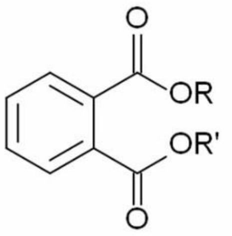
Toxicological Considerations

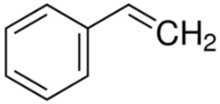
- Chemical and physical properties, either alone or in combination, make micro/nanoplastics potentially toxic
  1) Size
  2) Chemical composition
  3) Serve as a vector

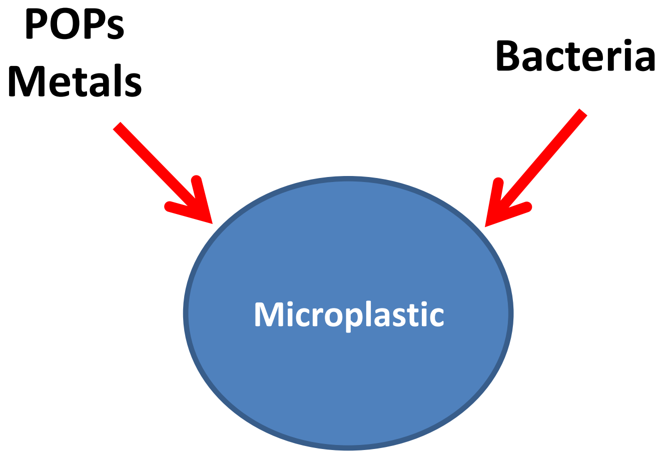


Thompson (2015), In *Marine Anthropogenic Litter*.









Toxicological Considerations (cont'd)

1) Size: ingestion/uptake by organisms
   - Potential for bioaccumulation and biomagnification
   - Microplastics: cross the gut (?), intestinal blockage, tissue abrasion
   - Nanoplastics: more likely to cross the gut, enter systemic circulation, and interact with biological macromolecules

2) Chemical composition
   - Composed of monomeric units: bisphenol A, styrene, vinyl chloride
   - Additives of plastics
     - Plasticizers (phthalates)
     - Antimicrobials (triclosan)
     - Flame retardants (polybrominated diphenyl ethers)

Toxicological Considerations (cont'd)

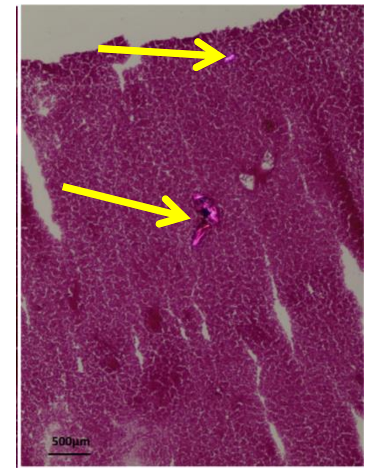
3) Serve as a vector
   - For chemicals: high surface area to volume ratio and hydrophobicity
     - Adsorb, concentration, and release environmental pollutants (e.g., polychlorinated biphenyls, polycyclic aromatic hydrocarbons, organochlorine pesticides, cadmium, chromium, lead)
   - For pathogens
     - Microbial communities found on microplastics
     - Introduction of invasive species

Potential for Human Exposure

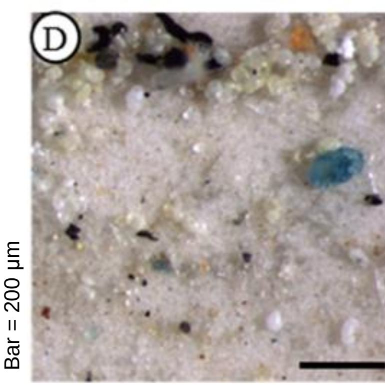
- No peer-reviewed research has been identified that directly assessed human exposure to environmental microplastics

- Environmental measurements and ecological observations provide insight regarding human exposure

- Oral exposure is likely to be the main route of human exposure
  - **Bivalves**
    - Found in farm-raised mussels and oysters
    - Potential human exposure to 11,000 microplastics pieces per year
  - **Finfish**
    - Found in gastrointestinal tracts
    - Possibility for translocation across the gut, into circulation, and embedded into edible tissue
    - Lab experiments demonstrate microplastics in liver
  - **Table salt**



Bar = 500 μm



Bar = 200 μm

Sources: bivalve data, Van Cauwenberghe et al (2014). 193: 65.
liver section, Avio et al (2015). 111:18; salt sample, Yang et al (2015). 49:13622

Potential for Human Health Effects

- No peer-review research has been identified that directly assessed human health effects of environmental microplastics

- Nanoparticles may offer insight regarding potential human health effects of micro/nanoplastics
  - Carbon nanotubes, silicon dioxide, metal-base nanomaterials
  - Reported biological observations[1]: systemic distribution, liver damage, inflammation, changes in gene expression
  - Biological interactions based on physical and chemical properties[1]: size, chemical composition, surface properties (e.g., chemistry, reactivity), chemical additives, adherent environmental chemicals

1) Reviewed in Bouwmeester et al (2015). 49:8932

Potential for Human Health Effects (cont'd)

- Laboratory studies using micro- and nano-sized plastic particles regarding drug delivery and nanoparticle inhalation (e.g., air pollution)

Model	Polymer and size	Observation
Human alveolar epithelial cells	Polystyrene, 240 nm	Phagocytosis
Human placenta (*ex vivo*)	Polystyrene, 50–240 nm	Tissue uptake and distribution
Human airway smooth muscle cells	Polystyrene, 40 nm	Decreased cell contractility
Human endothelial cells (from blood vessels)	Polystyrene, 20 nm	Cellular damage (e.g., apoptosis and necrosis)
Representative data, adapted from Leslie (2011). *Microplastic litter in the Dutch marine environment*.		

Microplastics and New Jersey

- The impact of microplastics on New Jersey is unclear

- Large pieces of plastic debris present in New Jersey waters

- Population density is a factor that may influence abundance of microplastics
  - New Jersey is the most densely populated state
  - Close to highly populated cities (New York City and Philadelphia)

- New Jersey is likely receiving microplastics from neighboring states or other geographical locations (e.g., wastewater treatment plant effluent from state of NY enters into Delaware and Hudson Rivers and the Atlantic Ocean)

- Aquatic species harvested in New Jersey may contain microplastics

- NJDEP tasked Public Health Standing Committee of NJ Science Advisory Board to investigate the potential human health impact of microplastics and nanoplastics
  - Exact findings and recommendations to NJDEP not yet publically available, eventual posting on NJDEP website (http://www.state.nj.us/dep/sab/)

Summary

- Microplastics have been found throughout the world, primarily in aquatic environments.
- Because of their size and ability to adsorb and release chemicals, microplastics may have ecological impacts.
- Microplastics have been found in species (e.g., shellfish) consumed by humans raising the possibility for human exposure and health effects.
- More research is needed to understand microplastics in New Jersey
and in general.

Credit: 5Gyres